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Full Length Research Paper

Evaluation of mineral content and functional properties of fermented maize (Generic and specific) flour blended with bambara groundnut (*Vigna subterranean* L)

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The mineral content, essential amino acids and selected functional properties of composite blend of maize flour (MF) and boiled bambara groundnut flour (BGF) in the ratio 70:30 w/w were investigated using standard processing technique. Results obtained showed that maize flour blended with 30% bambara groundnut in addition to germination significantly improved the mineral and amino acids profile of the composite blend. Functional properties (bulk density, water absorption capacity and foam capacity) were also affected by fermentation, which significantly lowered the water absorption capacity and bulk density increased the foam capacity of bambara-maize'ogi'. Sensory evaluation indicated that the bambara-maize'ogi' was generally acceptable. The application of bambara groundnut blend to traditional foods suggests a viable option for promoting the nutritional qualities of Africa maize-based traditional foods with acceptable cooking qualities.

Key words: Fermented maize flour, bambara groundnut, mineral content, functional properties.

INTRODUCTION

Consumption rate of maize and maize based product is grossly increasing in Nigeria. The sudden change could be attributed to eating habits as a result of poverty, which has become a chronic problem in developing countries, whereby parents are unable to afford high quality foods for their families (Cole et al., 1989).

Many Nigerians are now consuming less quality foods at the expense of what they need for a healthy life. Several studies have fortified local starchy foods with legumes like soybean, groundnut, bambara groundnut e.t.c, in order to improve their nutritional qualities. Bambara groundnut is essentially grown for human consumption. The seed makes a complete food, as it contains sufficient quantities of protein, carbohydrate and fat. Several researchers have examined the biochemical composition of the seed (Owusu-Domfeh et al., 1970; Oluyemi et al., 1976; Oliveira, 1976; Linnemann, 1987).

On the average, the seeds were found to contain 63% carbohydrate, 19% protein and 6.5% oil. Its protein content can be used to fortify our mostly starchy foods like 'ogi', made from maize (Mbata et al*.,* 2007).

Maize (Zea *mays*) grains are used in the production of several traditional foods, unfortunate they lack adequate micronutrients. In order to help alleviate the ever-increasing problems of malnutrition in developing countries, the need for fortification of popularly consumed low protein staple foods with inexpensive sources of plant proteins cannot be overemphasized.

The United Nation's Children Fund (UNICEF) (1998) estimated that approximately one out of three children younger than 5 years of age are chronically malnourished and are thus trapped early in life in a pattern of ill health and poor development. Malnutrition is thus associated with more than half of all deaths of children worldwide (Sobo and Oguntona, 2006). According to Onyezili (1999), malnutrition contributed to more than half a million death of babies born in Nigeria in 1999. These nutriational deficiencies are also known to lead to a high death rate, disabling diseases and retardation in physical growth and mental development (Banigo et al., 1986).

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This tends to reduce the population of the affected country.

Growth of infants in the first two years of life is very rapid. Food dependency is typically on breast milk which is reputed to be the best for human infants. However, the rapidity of growth mentioned earlier shows the need to supplement breast milk in meeting the nutritional requirement of the older child, hence, the need for nutritional supplements (Martorell et al., 1994).

Weaning foods in most African countries are usually in the form of cereal gruels which are watery suspensions of cooked maize, rice or sorghum (Onilude et al., 1999) that are very much low in quality protein.

In Nigeria and other parts of West Africa, cereal grains lack two essential amino acids, lysine and tryptophan (FAO, 1985; Hoshiai, 1991), thus making their protein quality poorer compared to that of animals (Chavan and Kadam, 1989).

Earlier studies have documented increased lysine and tryptophan in germinated corn (Tsai et al., 1975), improved vitamin content in germinated sorghum and maize (Asiedu et al., 1993), increased amino acid and vitamins in fermented blends of cereals and soybeans (Onilude et al., 1999).

Many brands of low-cost proprietary weaning foods have been developed from locally available, high-calorie cereals and legumes in tropical Africa (Price et al., 1978). Most cereals are low in essential minerals such as calcium, potassium, iron and zinc (Oyenuga, 1969) and blending cereals with legumes rich in proteins and essential amino acids has also been perfected (Livingstone et al., 1993).

To be useful and successful in food application, fermented maize flours fortified with a legume protein, bambara groundnut, should possess desirable functional and micronutrients properties. However, there are no information on the functional properties and micronutrient status of fermented maize flour blended with bambara groundnut. This study, therefore, aimed at the determination of functional properties, mineral content and amino acids of fermented maize flour blended with bambara groundnut.

MATERIALS AND METHODS

Collection of sample

Yellow maize (*Zea mays* L) and cream coat bambara groundnut (*Vigna subterranean* L) used were purchased from an Eke Awka market in Anambra state, Nigeria. The samples were thoroughly cleaned by picking all broken kernels, stones, together with other foreign particles and the good ones were sorted out. The samples were then stored in sterile polyethylene bags and taken to the laboratory for mineral content and functional analyses.

Pre-treatment of bambara groundnut

The bambara groundnut was first thoroughly cleaned by picking all the stones and other foreign particles present in them while sorting out the good ones. The cleaned bambara groundnut were soaked in water for 1 h and boiled at a temperature of 100°C for 20 min. The seeds were dehulled manually, sun-dried for 2 - 3 days. The dried seeds were then dry-milled into flour using a disc attrition mill (Hunt No. 2A premier mill, Hunt and Co, UK) to an average particle size of less than 0.3 mm. The milled grain was then sieved through a fine mesh (0.5 μm) to obtain the bambara groundnut flour.

Preparation of traditional fermented maize flour

Two hundred grams of the cleaned maize samples were soaked in plastic bucket containing 300 ml of distilled water and steeped for 24 h at room temperature (28 ± 2°C). The steep water was discarded by decantation and the steeped grains were germinated (48 h) by spreading on a clean grease free tray pan and thereafter it was sun dried for 2 - 3 days by putting it in a sterilized tray pan.

The maize grains were then milled using a disc attrition mill (Hunt No. 2A premier mill, Hunt and Co, UK) to an average particle size of less than 0.3 mm. The milled grain was then sieved through a fine mesh (0.5 μm) to obtain the maize flour.

Supplementation of fermented sorghum with soybeans

The bambara groundnut and maize flours were mixed together in the ratio 30:70 (w/w) (Bressani and Elias, 1974) (Figure 1).

Chemical analysis

Calcium (Ca), copper (Cu), Iron (Fe), Iodine (I_2), zinc (Zn), and magnesium (Mg) were determined using the atomic absorption spectrophotometer method as described by AOAC (1998).

Amino acid analysis

Lysine concentration in the sample was determined in triplicates, by digestion under vacuum with 6 M HCl in sealed ampules at 110°C for 22 h. The hydrolysates were derivatized and analyzed for amino acids on a water HPLC system controlled by Millenium 2010 software (Water DIV, Millipore Corp, Milford, MA, USA) (Millipore, 1987). Tryptophan was determined according to the AOAC (1998) method.

Functional properties

The bulk density was determined using the method of Wang and Kinsella (1976). Ten grams of the sample material were placed in a 25 ml graduated cylinder and packed by gentle tapping of the cylinder on a bench top 10 times from a height of 5 - 8 cm. The final volume of the test material was recorded and expressed as g/ml.

The method described by Cegla et al. (1977) was used in the determination of water absorption capacity (WAC). 6 g of materials were weighed in a 100 ml beaker. A known volume of water was pipetted into the beaker. The wet material was carefully stirred and allowed to equilibrate for 1 h at 26°C. After complete water absorption, the sample was further treated with 0.01 ml water portions with 10 min interval before visual observation. The volume that gave a complete absorption of water (no visible free water) was recorded. WAC was calculated as the ratio of maximum volume in g absorbed by 100 g dry material.

The foam capacity (FC) was determined as described by Naranyana and Narasinga-Roo (1982). In this method, the volume of foam at 60 s after whipping was expressed as FC.

Sensory evaluation

Fresh samples of cooked porridge prepared with each of the pro-

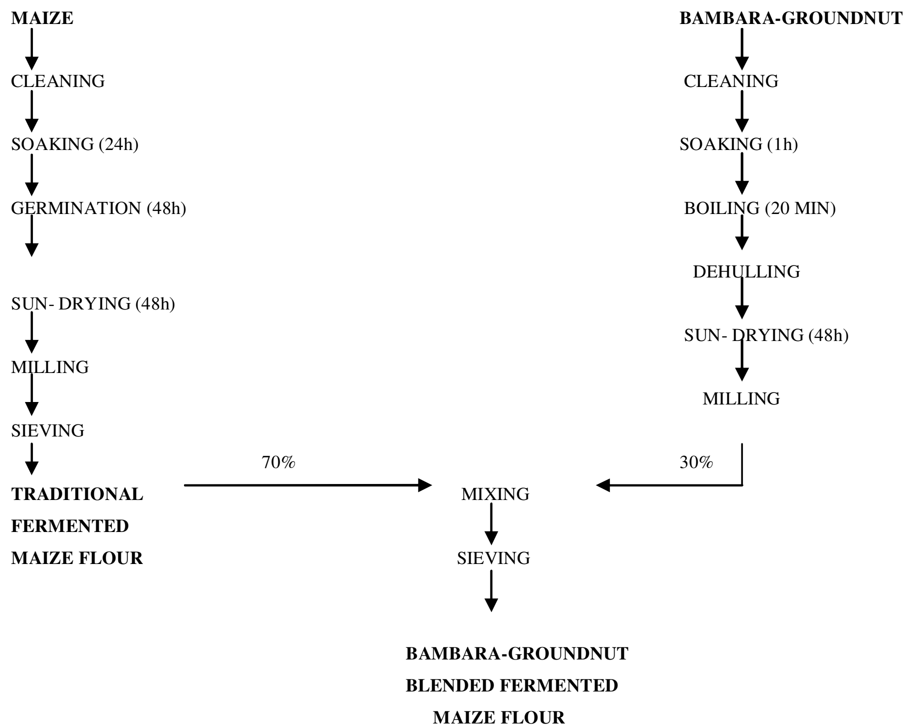

Figure 1. Flow diagram for the production of bambara-groundnut-blend and traditional fermented maize flour samples.

ducts by boiling 10% (w/v) slurry of the dough for 15 min were assessed for colour, texture, flavour (aroma), taste and overall acceptability. An 8 point hedonic scale, where 8 represented the highest score and 1 the lowest was employed to test the product for flavor, taste, texture, colour and general acceptability. The hedonic scaling used is thus: **No. 2 2007**

8 = like extremely
7 = like very much
6 = like moderately
5 = like slightly
4 = dislike slightly
3 = dislike moderately
2 = dislike very much and
1 = dislike extremely

Each treatment was evaluated three times by each panelist.

Consumer panel which was randomly selected from students and lecturers of the Department of Applied Biochemistry and Food Technology, Nnamdi Azikiwe University Awka, Nigeria, participated in the testing sessions. The assessments were conducted in a well lit room designed for sensory evaluation. The food was stored safely in a cool and dry place and served immediately or soon after preparation. Each judge was presented with a glass of water after each testing session to rinse their mouths so as to prevent carry-over effect.

Statistical analyses

The data were subjected to analysis of variance in a completely randomized design using the method of Stell and Torrie (1980). Significance difference was accepted at $p \leq 0.05$ levels.

RESULTS

The mineral composition of fermented maize flour and bambara groundnut-maize fortified flour of the diets are presented in Table 1. The zinc, iron, iodine, magnesium, and calcium contents of the flours ranged from 62.84 - 78.20, 49.72 - 58.80, 3.00 - 18.12, 460.02 - 475.20 and 115.64 - 128.40 mg per 100 g dry flour for fermented maize and bambara groundnut-maize fortified flours respectively. The flours especially those of bambara-maize ‘ogi’ supplied adequate amounts of most minerals except copper (24.60 - 29.75 mg).

The functional properties (bulk density, water absorption capacity and foam capacity) of the diets are presented in Table 2. The bambara groundnut-maize flour has a lower bulk density (0.35 g/cm^3) than the fermented maize flour (0.55 g/cm^3).

The water absorption capacity was also lower (41.5 g/g) in bambara groundnut-maize flour than in fermented maize flour (44.5 g/g). Foam capacity values increased in bambara groundnut-maize flour (44.5 g/g) than in fermented maize flour (41.5 g/g).

Table 3 shows the amount of bioavailable lysine and tryptophan in fermented maize and bambara groundnut-maize flours. The result showed an appreciable increase in lysine and tryptophan concentration in bambara groundnut maize flour. The overall acceptability scores of the various sensory attributes are shown in Table 4.

Table 1. The mineral content of the bambara groundnut-maize blended flour (mg/100g).

Elements	Fermented maize flour (MF)	Bambara groundnut-maize blended flour (BGF)
Copper (Cu)	29.75[a]	24.60[b]
Zinc (Zn)	62.84[c]	78.20[d]
Magnesium (Mg)	460.02[e]	475.20[f]
Calcium (Ca)	115.64[g]	128.40[h]
Iron (Fe)	49.72[i]	58.80[j]
Iodine (I_2)	3.00[k]	18.12[l]

Means of three independent determinations.
Mean values within a row with different superscripts differ significantly ($p < 0.05$).

Table 2. Functional properties of the bambara groundnut-maize blended flour.

Properties flour (BGF)	Fermented maize flour (MF) blended	Bambara groundnut maize
Bulk density (g/cm^3)	0.55[a]	0.35[b]
Water absorption capacity (g/g)	44.5[c]	41.5[d]
Foaming capacity (%)	0.16[e]	0.61[f]

Means of three independent determinations. Mean values within a row with different superscripts differ significantly ($p < 0.05$).

Table 3. Amino acid content (g/16gN) of bambara groundnut-maize blended flour (BGF)

Properties	Traditional	Bambara groundnut-maize blended
Fermented	**Maize flour**	**Flour (BDF)**
Lysine	0.50 ± 0.11[a]	4.20 ± 0.21[b]
Tryptophan	0.1 ± 0.08[c]	0.86 ± 0.06[d]

Means of three independent determinations.
Mean values in the same column with different superscripts differ significantly ($p<0.05$).

Table 4. Organoleptic characteristics and acceptability of bambara groundnut-maize blended dough

Mean scores [a, b]	Supplements	Colour Texture	Flavour	Taste	Overall
1	6.9	6.9	6.9	6.8	6.9
2	6.7	7.0	6.8	6.9	6.9
3	6.7	7.0	6.8	6.8	6.8
4	6.6	6.4	6.7	6.8	6.6
5	6.7	6.8	6.1	6.4	6.5

[a]Means are scores of 20 Judges and not significant ($p>0.05$) different b/w supplementary foods.
[b]Panelists used 8 point hedonic scale.

DISCUSSION

The study highlighted the need for fortification of maize fermented flour with bambara groundnut.

In tropical Africa, weaning foods based on cereals (maize) are deficient in essential amino acids such as lysine and tryptophan e.t.c, thus making their protein quality poorer compared to that of animals (Chavan and Kadam, 1989). However, most cereals are also low in essential minerals such as calcium, potassium, iron and zinc (Oyenuga, 1969) and blending with legumes rich in proteins and essential amino acids has been reported (Livingstone et al*.,* 1993; Mbata et al*.,* 2007). Despite the reported studies in the nutrient status of cereal based diets in sub-Saharan Africa, the nutrient needs of infants and sick adults are still not being met.

An earlier report by Mbata et al. (2007) considered the nutritional status (proximate, amino acid and rheological properties) of fermented maize meal by fortification with bambara groundnut. In the study, the effect of fortification of maize based traditional foods with legume protein bambara groundnut at 10% and 20% replacement levels on the rate of fermentation and organoleptic product quality were investigated. Though the nutritional status was enhanced, the composite blends of maize and bambara groundnut (70:30 w/w) as in the study, gave a better nutritional and supplemental relationship in the production of bambara-maize'ogi'. Addition of 30% bambara groundnut into bambara-supplemented maize improves the mineral and essential amino acid contents of maize 'ogi'.

'Ogi' has a poor biological value thus, children weaned entirely on 'ogi' made solely from maize are known to suffer from malnutrition and generally provide insufficient amounts of certain key nutrients (particularly iron, zinc and calcium) to meet the recommended nutrient intake during the age range of 6 – 24 months and so the need for enrichment (Dewey and Brown, 2003).

Results obtained from this study showed that there were significant improvement in the mineral and essential amino acid contents of maize blended meal with bambara groundnut. The minerals especially zinc, calcium, magnesium, iron and iodine increased with 30% addition of bambara groundnut. This increase could be due to the combination effect because maize and most cereals are deficient in essential micronutrients. The essential amino acids composition at the end of 72 h fermentation differed significantly ($P < 0.05$) from those of fermented maize meal. However, a varied pattern was noticed in the improvement of each amino acid in the blended sample. Lysine and tryptophan are essential amino acids which are vital for growth and maintenance of the body and are often limiting in some cereals (FAO, 1985; Asiedu et al., 1993a). Bambara-groundnut is very good nutritionally, rich in lysine. The incorporation of bambara-groundnut to maize meal increased these amino-acids content. This agrees with the finding of Wu and Wall (1980), who showed that germination of cereals followed by other processing techniques is essential to improving lysine content. The findings from this study have showed that the blended food (bambara-maize 'ogi') was nutritious, since the product met the recommended dietary allowance (RDA) with respect to mineral and essential amino acids as recommended by the Food and Agriculture Organization/World Health Organization (1985) and the National Institute of Nutrition (1992) for children, pregnant and lactating mothers.

The functional properties of the maize fermented meal and their blends are shown in Table 2. Bulk density (BD) of the formulations was low in bambara-maize'ogi' (0.35 g/ml) compared to that of maize fermented meal (0.55 g/ml). The water absorption capacities (WACs) of the bambara-maize'ogi' (which indicated the volume of water needed to form a gruel with a suitable thickness for child feeding) was also low (41.5 g/100 g) compared to that of maize fermented flour (44.5 g/100 g). The water absorp-tion capacities (WACs) of maize flour were significantly ($p < 0.05$) different from the water absorption capacities of bambara groundnut-maize'ogi'. However, a weaning food should have low WAC and BD in order to produce a more nutritious and suitable weaning food. This could be achieved by reducing the viscosity of the starchy components by malting (Malleshi and Desikachar, 1982). A low viscosity (less bulky) food contains higher nutrient contents since the volume of the food is low. The foam capacity (FC) was increased by fermentation and thus had a similar addition effect on the flour blends (Onimawo et al., 2007). Akubor and Obiegbuna (1999) reported similar effects on millet flour by germination. Fermentation may have caused surface denaturation of bambara groundnut proteins and reduced the surface tension of the molecules which gave good formability. In the organoleptic evaluation, the bambara-maize'ogi' were accepted by the trained panelists. Mean scores were not significantly ($p > 0.05$) different. This shows that the product was liked by the trained panelists.

Conclusion

The study showed that fermentation could improve both the amino acids, mineral contents and some selected functional properties of bambara groundnut.

This improvement invariably improved the essential amino acids, mineral contents and functional properties of the blends made from bambara groundnut and maize flours. This supplementation of 'ogi' with bambara groundnut increases the biological value of 'ogi' which reduced the occurrence of malnutrition and micronutrient deficiency in children weaned with 'ogi'. The bambara-maize 'ogi' produced from the blend was safe and generally acceptable and could be used in weaning, and improving birth weight.

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